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although 100 in the Wisconsin curve is as of February, 1915, the two curves are plotted in this way in order to show more clearly the similarity of movement. The line of normal increase of factory wage earners in New York State from 1904 to 1914—about 12 per cent for the five year period—is based on the figures of the United States Census of Manufactures.

The third chart, showing seasonal and other fluctuations in employment among organized wage earners in certain trades in New York State, 1904–15, is based on charts published in Bulletin No. 85 of the New York State Industrial Commission.

## A METHOD OF ESTIMATING THE POPULATION OF CONTINENTAL UNITED STATES FOR INTERCENSAL YEARS

By Donald R. Belcher*

The United States Department of Commerce publishes annually in its *Statistical Abstract* a table showing the estimated population of the United States by years over a considerable period, based on the returns of the decennial censuses of population. For the years prior to that of the latest census, the numerical increase in population in any year is assumed to be one-tenth of the numerical increase shown for the decade to which that year belongs. For years subsequent to the latest census, the annual increase is assumed to be equivalent to that assumed for the years of the preceding decade. These processes of estimation may be simply described as straight-line interpolation and straight-line extrapolation respectively.

It is probably true that until the beginning of the World War these methods yielded results that were not seriously misleading. But during the war a number of influences were at work, the net result of which was to restrict population growth in the United States. Indeed, straight-line extrapolation as applied to the years between 1910 and 1920 on the basis of the censuses of 1900 and 1910 showed an estimated population for 1920 nearly two millions greater than that actually determined by the 1920 census. And now that the 1920 returns are available, straight-line interpolation is equally unsatisfactory for determining the intercensal population during that decade, since it is apparent that these restrictive influences did not become operative until 1914.

An analysis of available statistics on births, deaths, immigration, and emigration during the period from 1910 to 1920 has been found to provide a fairly satisfactory basis for estimating the population growth for the intervening years. The purpose of this paper is to present the results of that analysis and to suggest a method which can be applied to the estimation of growth during the period prior to the taking of the 1930 census.

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The population of continental United States as shown by the last three census reports was as follows:

| | |
|---|---|
| June 1, 1900 | 75,994,575 |
| April 15, 1910 | 91,972,266 |
| January 1, 1920 | 105,710,620 |

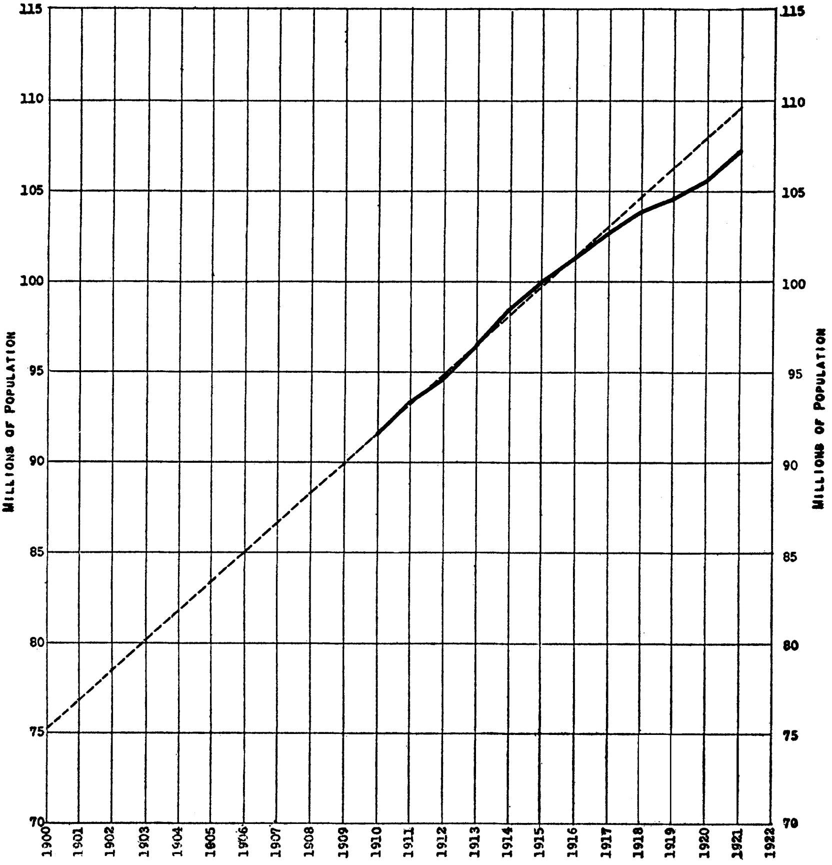
In order to make this study as of January 1 of each year, the 1910 census figure was moved back three and one-half months by the assumption of a straight-line growth between the June 1, 1900, and the April 15, 1910, censuses. The result is an estimated figure for January 1, 1910, of 91,500,350. The growth in population from this date to January 1, 1920, is then 14,210,270, or an average of 1,415,109 a year.

Data on immigration and emigration are available by months since July, 1907. The annual increase in population due to excess of immigration over emigration was computed throughout the period and is shown in Column 1 of Table I.

TABLE I

| Calendar year | Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|---|
| | Actual excess of immigration over emigration | Estimated deaths in United States | Estimated births in United States | Net annual increase in population |
| 1910 | 763,918 | 1,267,101 | 2,281,904 | 1,778,721 |
| 1911 | 326,041 | 1,302,498 | 2,325,953 | 1,349,496 |
| 1912 | 646,742 | 1,308,227 | 2,369,106 | 1,707,621 |
| 1913 | 1,017,957 | 1,254,036 | 2,413,496 | 2,177,417 |
| 1914 | 262,853 | 1,289,339 | 2,459,644 | 1,433,158 |
| 1915 | 43,005 | 1,293,987 | 2,506,196 | 1,255,214 |
| 1916 | 263,887 | 1,422,182 | 2,534,859 | 1,376,564 |
| 1917 | 80,702 | 1,452,152 | 2,588,486 | 1,217,036 |
| 1918 | 41,471 | 1,888,681 | 2,577,299 | 730,089 |
| 1919 | 4,636 | 1,377,331 | 2,401,140 | 1,028,445 |
| Total | 3,451,212 | 13,855,534 | 24,458,083 | 14,053,761 |

Data on the number of deaths annually in the registration states are available since 1900. Although the number of states reporting has varied considerably, it was possible to select twenty-one identical states for which data are available throughout the decade, 1910–20. The population of these states in 1910 was 53.4 per cent and in 1920, 54.6 per cent of the population of continental United States. The corresponding ratio for each of the intervening years was estimated by



ESTIMATED POPULATION OF CONTINENTAL UNITED STATES

ESTIMATES ARE AS OF JANUARY 1ST FOR THE YEARS 1900 AND 1910–1921, INCLUSIVE. FOR PURPOSES OF COMPARISON, A STRAIGHT-LINE PROJECTION OF THE 1900–1910 GROWTH IS ALSO SHOWN.

means of a straight-line interpolation between 53.4 per cent and 54.6 per cent. On the basis of these ratios and the actual number of deaths in the twenty-one states, the total number of deaths in the United States was estimated for each of these years (Column 2, Table I). It is true that the Bureau of the Census has published annual death-rates for the registration states. But these rates are based on population estimates secured by straight-line extrapolation since 1910 and are, therefore, considerably too low. For this reason it seems preferable to use the actual number of deaths.

The determination of the number of births offers additional difficulties, since the only data available are the number of births in each of the states for the year ending June 1, 1900, and in certain registration states by calendar years beginning with 1915. Comparison of the figures for ten identical states showed that although the number of births decreased decidedly in 1918 and in 1919, the figures for the years 1900, 1915, 1916, and 1917 were fairly consistent with a constant rate of increase. The number of births was therefore estimated for the years 1910–14 inclusive by means of this constant rate. These figures, however, are for ten states, the total population of which in 1910 was 30.68 per cent and in 1920, 30.71 per cent of that of the United States. These and interpolated ratios were then used to compute the estimated number of births in the United States (Column 3, Table I).

The annual population increases due to the net results of immigration, emigration, estimated deaths, and estimated births are shown in Column 4. The total of these increases is, however, slightly smaller than the actual population increase from 1910 to 1920. In other words, this total added to the 1910 census figure gives an estimated population for January 1, 1920, of 105,554,111, or 0.15 per cent lower than that shown by the census. On the other hand, the straight-line projection method, based solely on the 1900 and 1910 censuses, gives an overestimate of 1.86 per cent, or a percentage error more than ten times as great. Furthermore, straight-line interpolation between 1910 and 1920 is unsatisfactory because, as already pointed out, it fails to take into consideration the restrictive influences in effect during the latter half of the decade.

Estimates for the years between 1910 and 1920 have, therefore, been obtained from the increases shown in Column 4 by spreading the small cumulative error over the ten years. Table II shows for each year the resulting population estimate as of January 1, and an estimated growth during the year.

TABLE II

Estimated population of continental United States

| Calendar year | Population January 1 | Growth during the year |
|---|---|---|
| 1910 | 91,500,350 | 1,781,567 |
| 1911 | 93,281,917 | 1,355,186 |
| 1912 | 94,637,103 | 1,716,158 |
| 1913 | 96,353,261 | 2,188,798 |
| 1914 | 98,542,059 | 1,447,387 |
| 1915 | 99,989,446 | 1,272,288 |
| 1916 | 101,261,734 | 1,396,484 |
| 1917 | 102,658,218 | 1,239,801 |
| 1918 | 103,898,019 | 755,700 |
| 1919 | 104,653,719 | 1,056,901 |
| 1920 | 105,710,620 | 1,609,658 |
| 1921 | 107,320,278 | ......... |

As a matter of interest, the growth during 1920 has been estimated on the basis of actual immigration and emigration data and projected births and deaths in the registration states. This results, as shown also in Table II, in an estimated population of 107,320,278 for January 1, 1921. It is true, of course, that in applying this method to projections of future growth no information as to the trend of the ratio between the population of the selected registration states and that of the United States is available. The error involved in projecting the ratios found in the 1910–20 decade will probably not be appreciable.

The accompanying chart shows the population estimates for the years 1910 to 1921 inclusive, and a straight-line projection of the 1900–10 growth.

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# A SIMPLE GRAPHIC CONSTRUCTION FOR FARR'S RELATION BETWEEN BIRTH-RATE, DEATH-RATE, AND MEAN LENGTH OF LIFE*

By Alfred J. Lotka

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In a previous article† the writer has discussed the rational basis of Farr's rule‡

$$\frac{1}{3}\cdot\frac{1}{b}+\frac{2}{3}\cdot\frac{1}{d}=L \qquad (1)$$

where

$b$ = birth-rate per head (2)
$d$ = death-rate per head (3)
$L$ = mean length of life. (4)

Writing Farr's rule in the more general form

$$P\frac{1}{b}+Q\frac{1}{d}=L \qquad (5)$$

or

$$p\frac{1}{b}+q\frac{1}{d}=1 \qquad (6)$$

$$(b-p)(d-q)=pq \qquad (7)$$

it was shown in the paper cited how the values of $P$, $Q$ (represented in Farr's formula by the approximate numerical coefficients $\frac{1}{3}$ and $\frac{2}{3}$) could be determined exactly.

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* *Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health Johns Hopkins University.* No. 46.

† *Quart. Pub. Am. Statis. Assn.*, Sept., 1918, p. 121.

‡ Quoted by Newsholme, *Vital Statistics*, 1899, p. 301.